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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

FREE-FLIGHT ZERO-LIFT DRAG-RISE MEASUREMENTS OF EQUIVALENT BODIES OF REVOLUTION OF SEVERAL VERSIONS OF THE DOUGLAS XF4D-1 AIRPLANE AT TRANSONIC SPEEDS

TED. NO. NACA AD 394

By Grady L. Mitcham

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Langley Field, Va.

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON

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SUMMARY

Free-flight tests have been conducted with small equivalent bodies of revolution representing different versions of the Douglas XF4D-1 airplane to determine the reduction in drag that would result from various modifications to the airplane. Results indicated that, at Mach numbers greater than 1, considerable reduction in drag would result from a thinner wing and tail, a reduction in wing-fillet thickness, and modified forward and rearward fuselage lines.

INTRODUCTION

At the request of the Bureau of Aeronautics, Department of the Navy, the Langley Pilotless Aircraft Research Division has tested equivalent bodies of revolution of the Douglas XF4D-1 airplane and some proposed modifications to the airplane. These equivalent bodies of revolution which were designed according to the concept of the transonic area rule provide a simple and inexpensive means of estimating the zero-lift pressure drag and drag rise of complete airplane configurations. The purpose of these tests was to determine the incremental differences in drag that would result from various proposed modifications to the Douglas XF4D-1 airplane at transonic speeds. These modifications consisted of a thinner wing and tail, reduction in wing-fillet thickness, modified forward and rearward fuselage lines, and modified pilot's enclosure.

The drag measurements from five models are presented herein for Mach numbers varying between 0.73 and 1.24 at Reynolds numbers (based on body length) of about 8×10^6.

SYMBOLS

C_D	total-drag coefficient, $\frac{\text{Drag}}{\text{Dynamic pressure} \times \pi R_m^2}$
l	overall length
M	Mach number
R_m	maximum radius of body
r	body radius at station x
x	body station measured from nose

$\Delta C_D = C_D - C_{D_{m=\text{subsonic}}}$, based on wing area

MODELS AND APPARATUS

The general arrangement and some of the pertinent dimensions of the basic Douglas XF4D-1 airplane are given in figure 1. The dashed lines in figure 1 represent the general lines of the redesigned XF4D-1, which is referred to as the XF4D-2.

Four equivalent bodies of revolution, which represented various versions of the XF4D-1 and one Douglas reference body, were constructed and then flight tested by use of the helium gun at the Pilotless Aircraft Research Station at Wallops Island, Va.

A photograph of the helium gun is shown as figure 2. The model is positioned in the breech by means of a 6-inch-diameter sabot. A cutaway photograph of a sabot and model is shown as figure 3. Also shown in this photograph is the push plate which bears against the assembly and accelerates the model to supersonic velocities when the quick-opening valve admits helium into the breech under about 200 lb/sq in. pressure. Upon emerging from the 23-foot barrel, the three segments of the sabot and the push plate peel away and fall to the ground within 50 yards; then the model decelerates along a ballistic trajectory during which period a continuous velocity time history and trajectory are obtained by means of the

CW Doppler velocimeter and an NACA modified SCR 584 radar tracking unit, respectively.

The models were fin-stabilized bodies of revolution having the same longitudinal distribution of cross-sectional area as the corresponding airplane configurations. This similarity was accomplished by subtracting the fin cross-sectional area from the equivalent body area at corresponding stations. A brief description of each model is given as follows:

Model A: Equivalent body of revolution of the rocket-powered drag model tested without external stores in reference 1. The ratio of maximum cross-sectional area to wing area was 0.0758.

Model B: Equivalent body of revolution of the production version of the XF4D-1 airplane. The ratio of maximum cross-sectional area to wing area was 0.0758.

Model C: Equivalent body of revolution of an improved version of the XF4D-1 airplane which included the following changes:

(1) Improved rear fuselage lines

(2) Reduced fillet thickness

(3) Improved pilot's enclosure

(4) Reduced vertical-tail thickness

The ratio of maximum cross-sectional area to wing area was 0.0704.

Model D: Equivalent body of revolution of the XF4D-2 airplane, which incorporates the following changes to the XF4D-1 airplane:

(1) Increased forebody length

(2) Wing thickness reduced from 7 to 5 percent at the root chord and from 4.5 to 3.2 percent at the tip chord

(3) Reduced fillet thickness

(4) Modified rear fuselage lines

(5) Modified pilot's enclosure

(6) Reduced vertical-tail thickness

The ratio of maximum cross-sectional area to wing area was 0.0619.

Model E: A Douglas reference body of revolution (included at the request of the contractor).

The nondimensional radius distribution and cross-sectional area distribution for $M = 1.0$ of the various versions of the XF4D airplane and the reference body are given in parts (a) and (b) of figures 4 to 8. Open inlets were simulated by subtracting from the total cross-sectional area between the inlet and exit stations a constant stream-tube area (2.96 sq ft) equal to the inlet area times the mass-flow ratio at Mach number 1.0.

DATA REDUCTION AND ACCURACY

The CW Doppler velocity-time variation was differentiated to give the model acceleration as a function of time. The velocities measured by Doppler radar were then corrected to true airspeeds by vector addition of the wind velocity. Model position in space was determined by means of a modified tracking-radar set. The flight-path angles were thus obtained and used to eliminate the gravity component from the total acceleration, and the drag force on the model was then calculated from this corrected acceleration and the model weight. Free-stream temperature and static pressure (obtained from a radiosonde released at firing) were used together with the flight path to obtain the variation of air density and velocity of sound with time; these variations were used to calculate the drag coefficients from the drag forces obtained as above. The effect of the fins is negligible since the pressure drag of the fins, which was initially low, was further reduced by suitably indenting the bodies in the region of the fins.

The accuracy of the measurements is believed to be within the following limits:

C_D (based on wing area). . . . . ±0.001
M . . . . ±0.01

RESULTS AND DISCUSSION

The measured drag coefficients C_D based on the maximum cross-sectional area of each equivalent body of revolution for the various versions of the Douglas XF4D airplane and of the Douglas reference body are given in parts (c) of figures 4 to 8. The ΔC_D for these configurations, based on the scaled-down wing area of the XF4D airplane, 557 square feet, is given in figure 9. The ΔC_D obtained from the rocket-model test (ref. 1) is also presented for purposes of comparison with its corresponding equivalent body. The agreement between the drag-rise Mach number $\left(\text{where } \Delta C_D/\Delta M = 0.1\right)$ and the ΔC_D for the rocket model and its equivalent body of revolution (model A) is shown to be good. This agreement is consistent with the concept of the transonic area rule of reference 2 which states that the zero-lift drag rise of thin, low-aspect-ratio wing-body combinations is primarily dependent on the axial distribution of cross-sectional area of the configuration and that the drag rise of any such configuration is approximately the same as that of its equivalent body of revolution. Experimental results presented in reference 3 of several tests of complete airplane configurations and their equivalent bodies of revolution serve to substantiate the concept of the transonic area rule, particularly for airplanes with delta-wing plan forms.

The modifications incorporated in the XF4D-2 airplane (model D) reduced the pressure drag of the XF4D-1 production airplane (model B) by about 28 percent at $M = 1.1$, whereas those incorporated in model C resulted in only an 8-percent reduction in the pressure drag. The drag-rise Mach number for the XF4D-2 airplane was about 0.03 higher than that of the other configurations tested.

CONCLUDING REMARKS

Results from free-flight tests of equivalent bodies of revolution, representing proposed modifications to the Douglas XF4D-1 airplane, indicated that large decreases in drag may be obtained at Mach numbers greater than 1 by using a thinner wing and tail, reducing the wing-fillet thickness, and modifying the forward and rearward fuselage lines.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., October 21, 1954.

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Aeronautical Engineer

Approved: Joseph A. Shortal

Joseph A. Shortal
Chief of Pilotless Aircraft Research Division

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1. Mitcham, Grady L., Blanchard, Willard S., Jr., and Hastings, Earl C., Jr.: Summary of Low-Lift Drag and Directional Stability Data from Rocket Models of the Douglas XF4D-1 Airplane With and Without External Stores and Rocket Packets at Mach Numbers from 0.8 to 1.38 - TED No. NACA DE 349. NACA RM SL52G11, Bur. Aero., 1952.

2. Whitcomb, Richard T.: A Study of the Zero-Lift Drag-Rise Characteristics of Wing-Body Combinations Near the Speed of Sound. NACA RM L52H08, 1952.

3. Hall, James Rudyard: Comparison of Free-Flight Measurements of the Zero-Lift Drag Rise of Six Airplane Configurations and Their Equivalent Bodies of Revolution at Transonic Speeds. NACA RM L53J21a, 1954.

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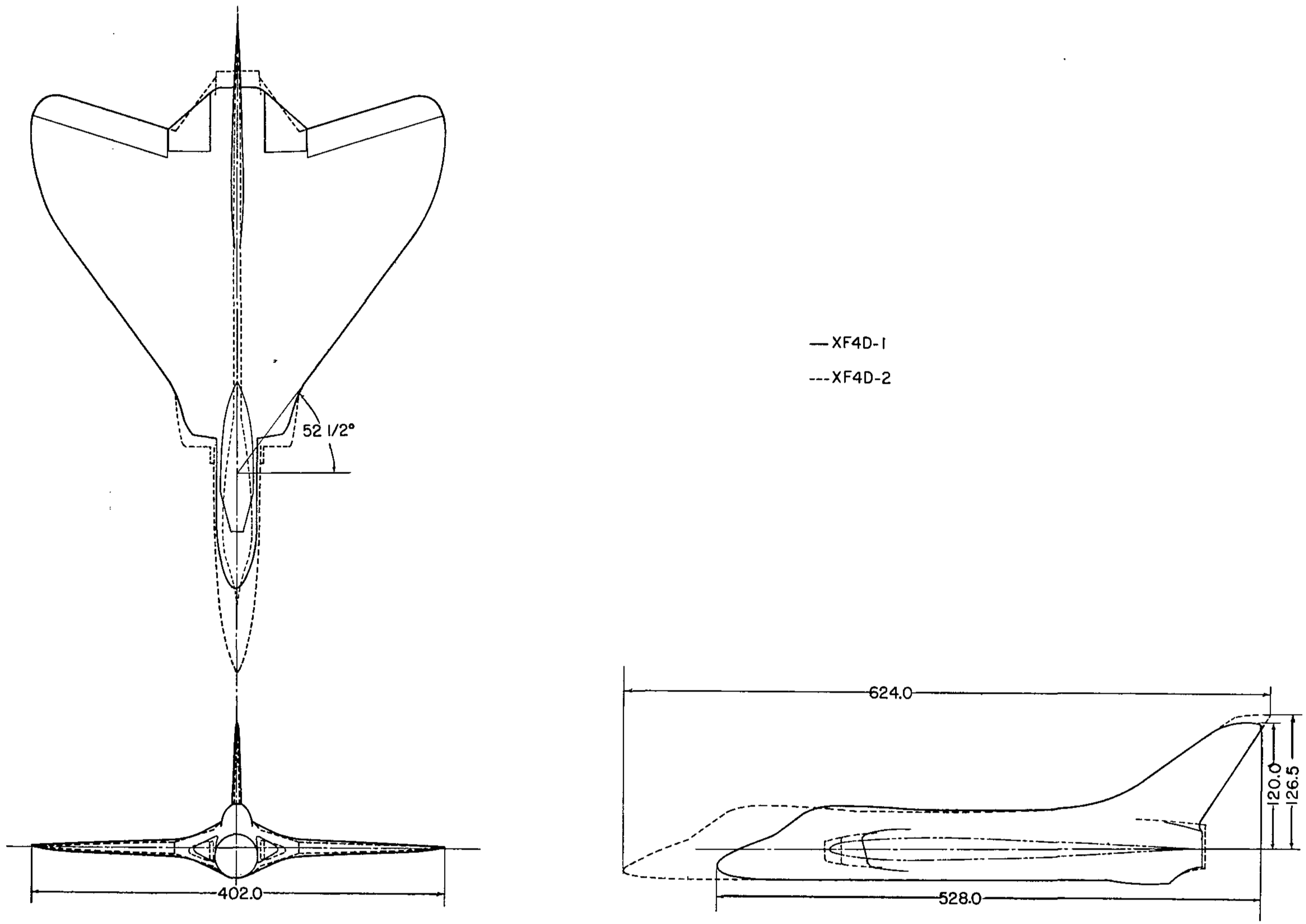
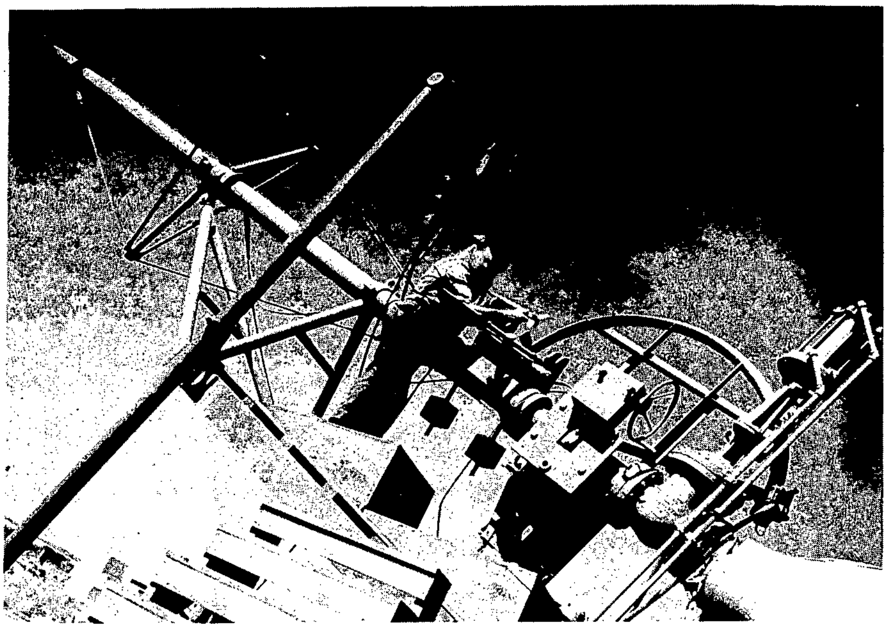


Figure 1.- Three-view drawing of the Douglas XF4D-1 and XF4D-2 airplanes. All dimensions are in inches.

[redacted]



(a) Model being placed in helium gun.

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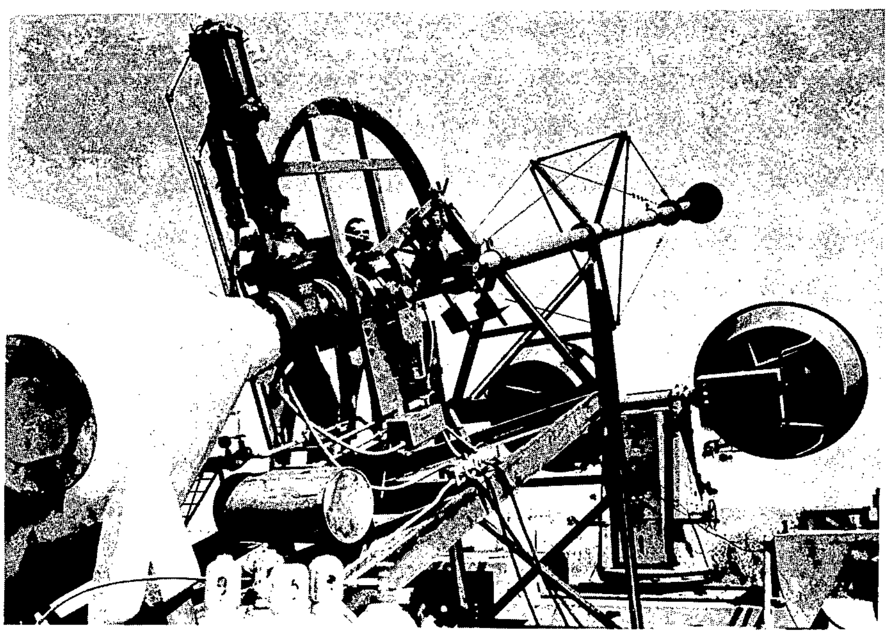

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(b) General arrangement showing helium supply tank, quick-opening-valve mechanism, barrel and barrel truss, and CW Doppler velocimeter used to track model.

Figure 2.- Helium gun.

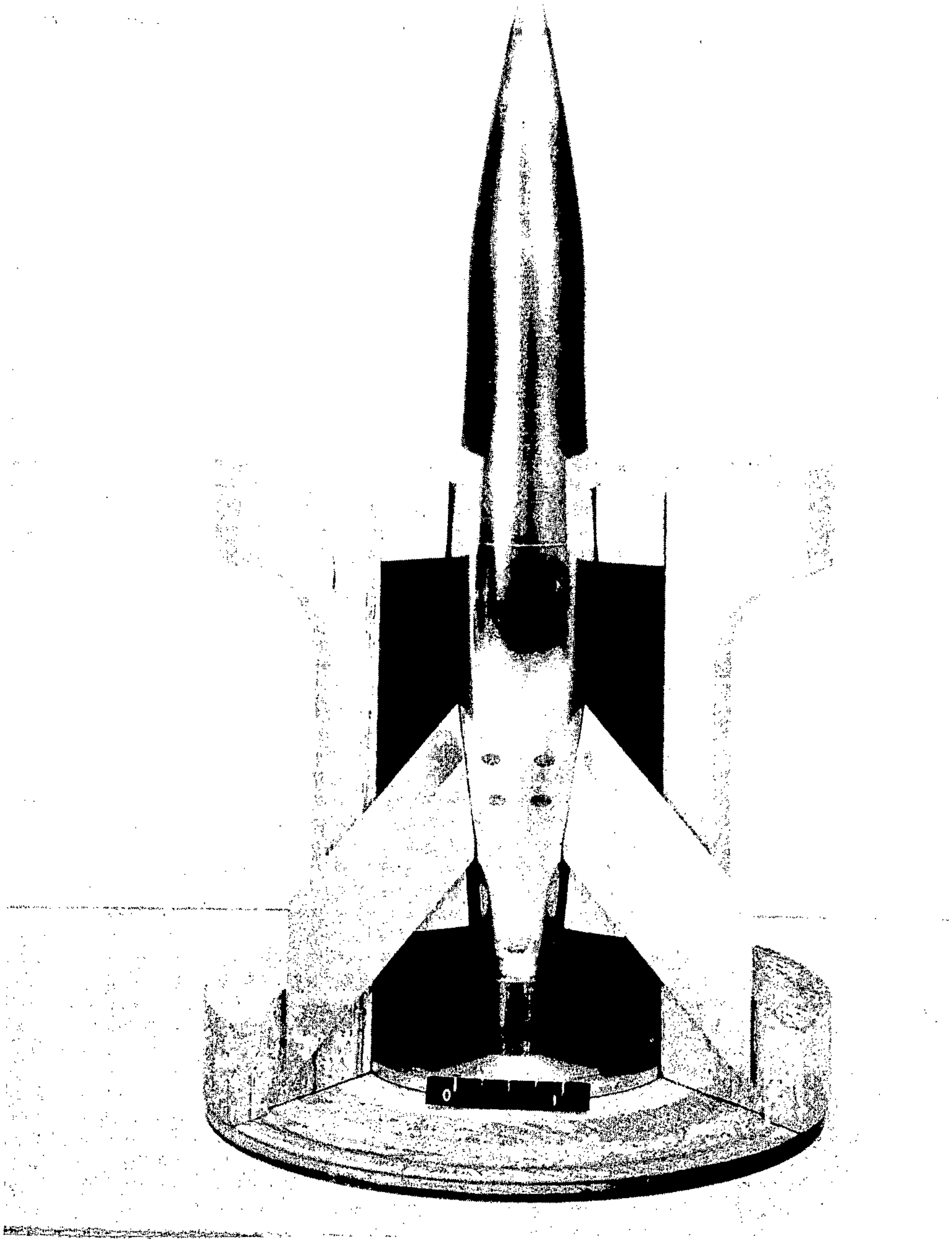

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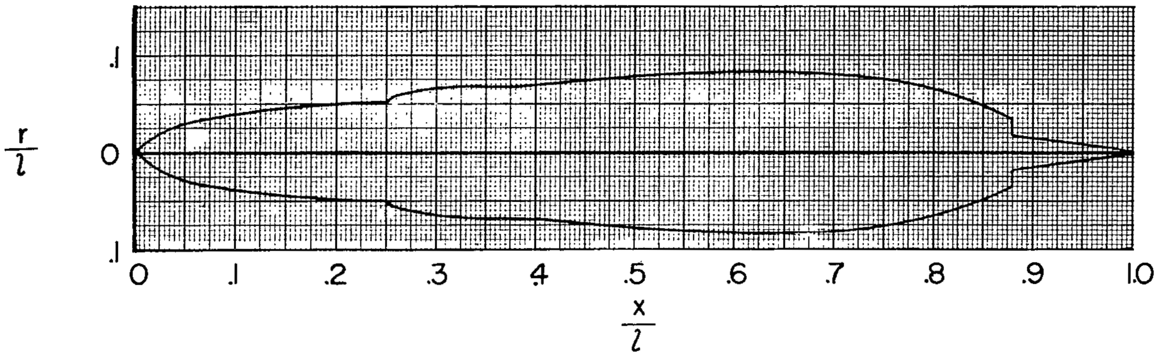
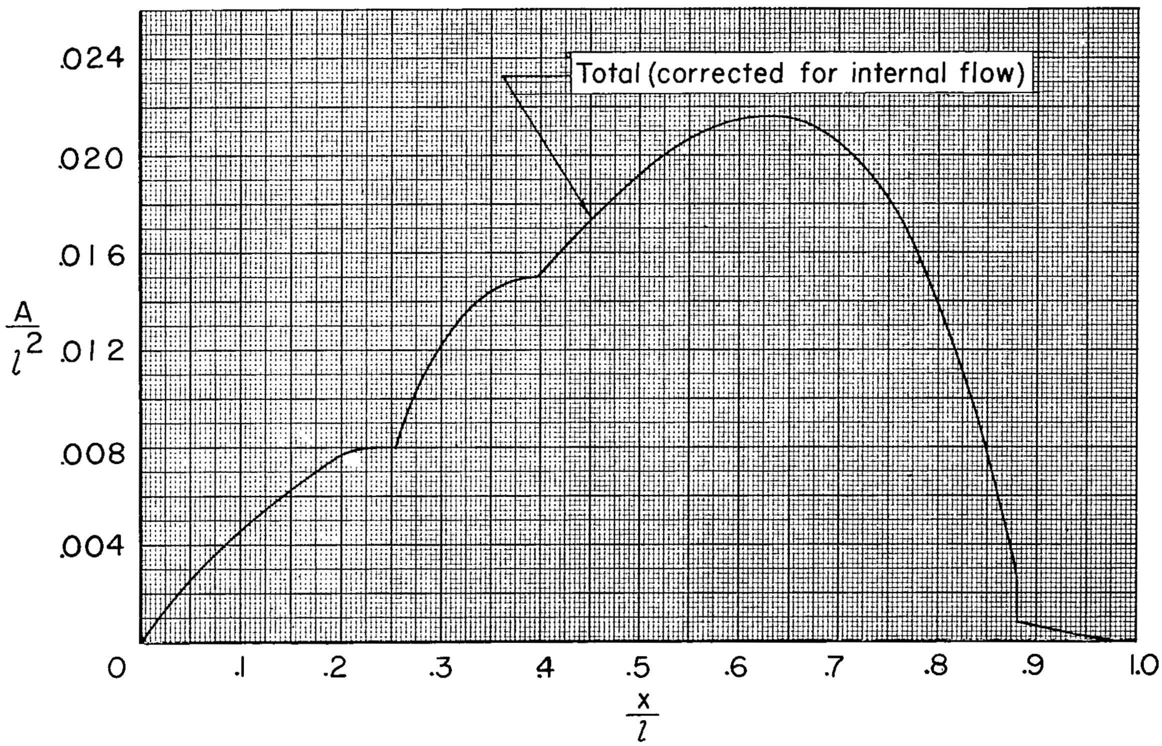
Figure 3.- Cutaway photograph of typical model mounted in sabot.

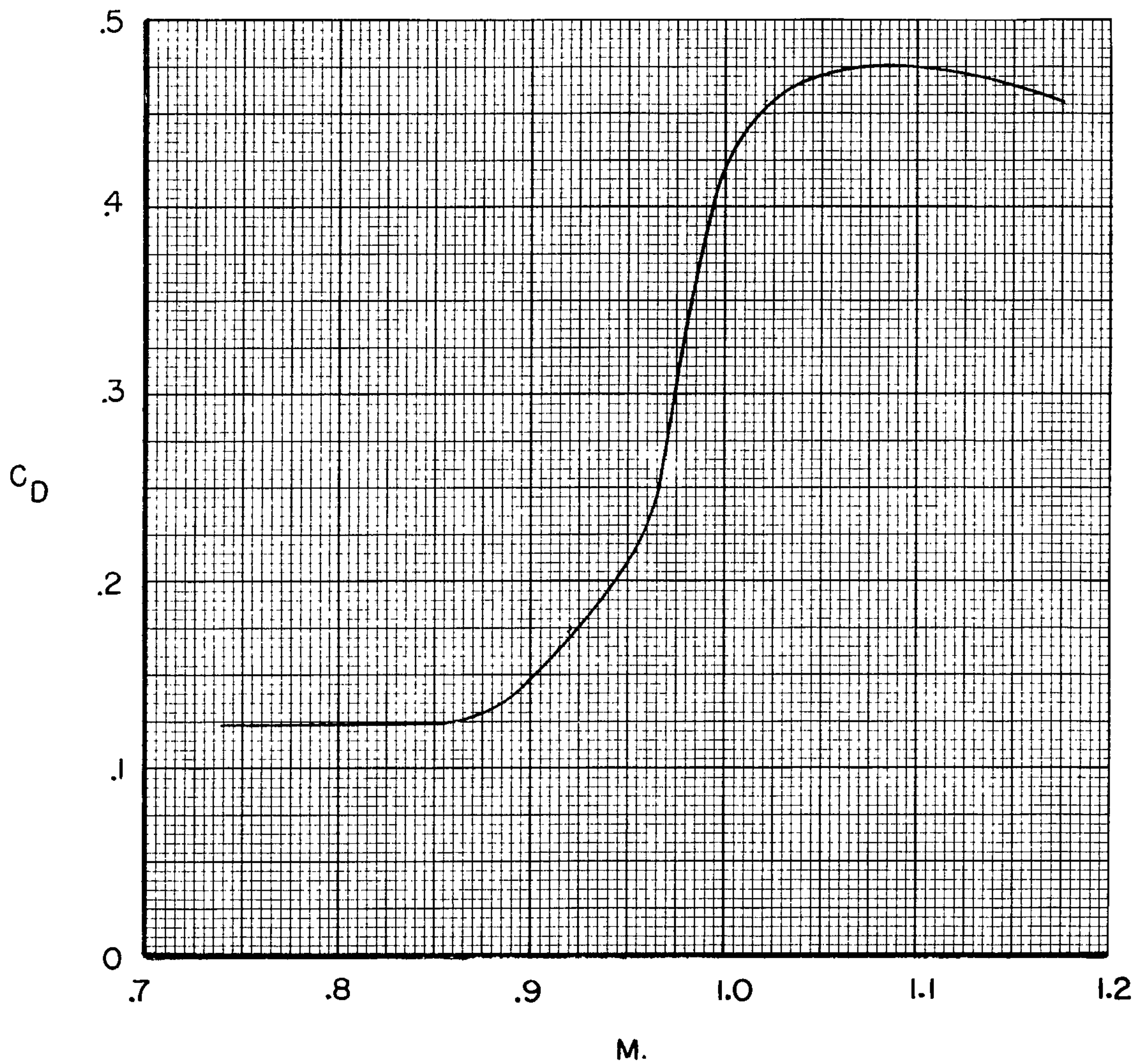


(a) Equivalent body of revolution.



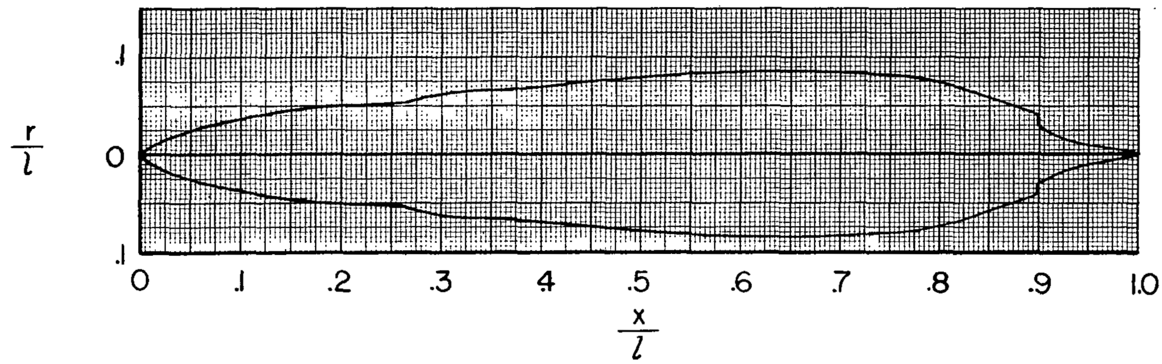
(b) Area distribution.

Figure 4.- Model A.

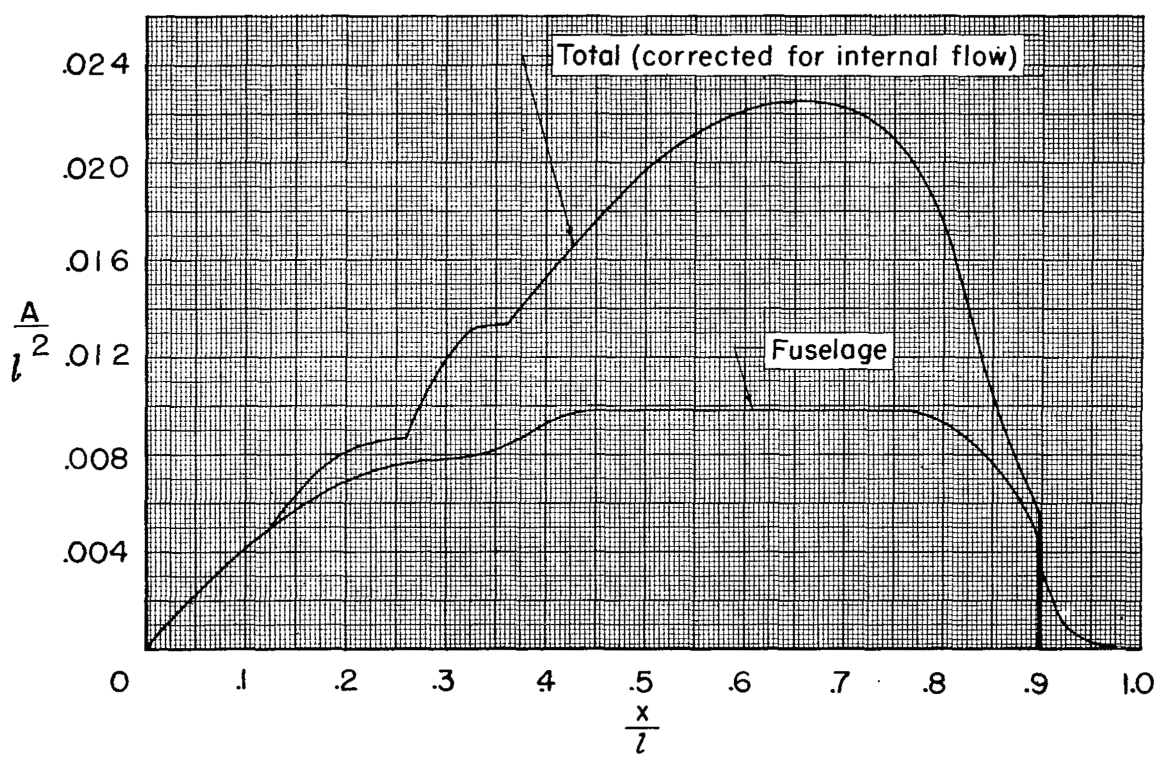


(c) Drag coefficient.

Figure 4.- Concluded.



(a) Equivalent body of revolution.



(b) Area distribution.

Figure 5.- Model B.

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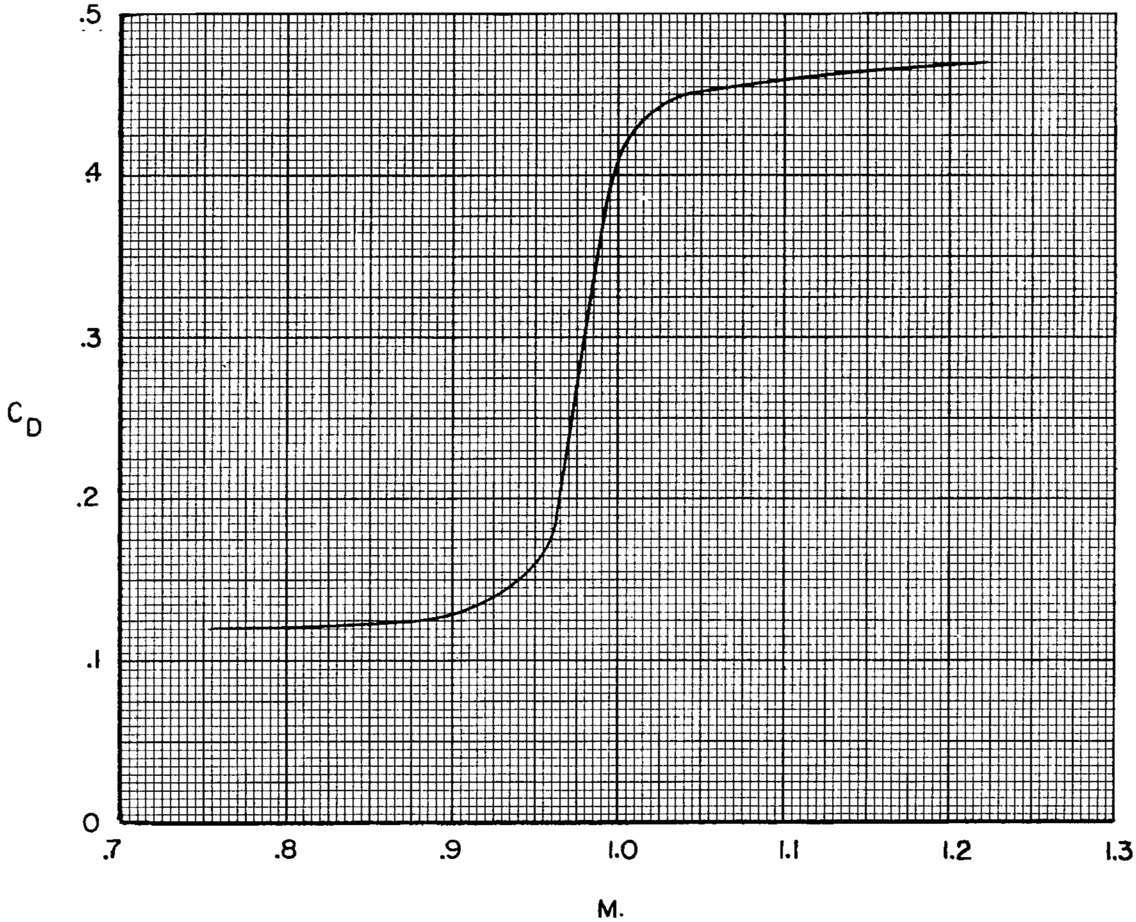

(c) Drag coefficient.

Figure 5.- Concluded.

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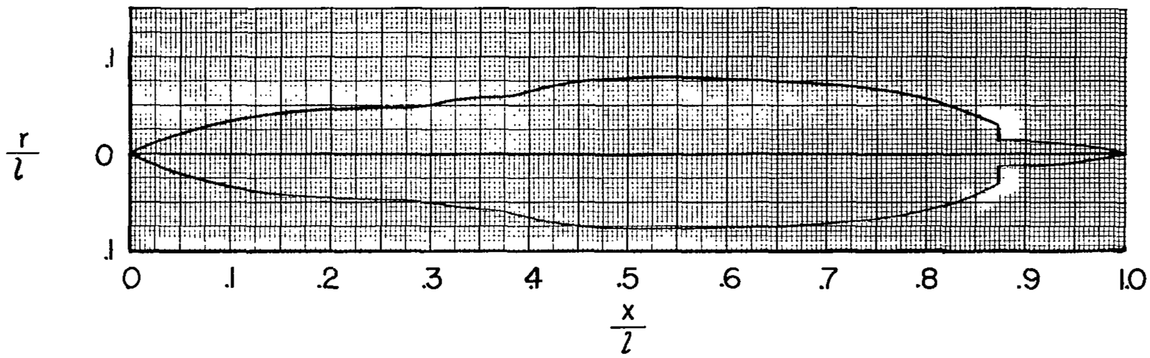
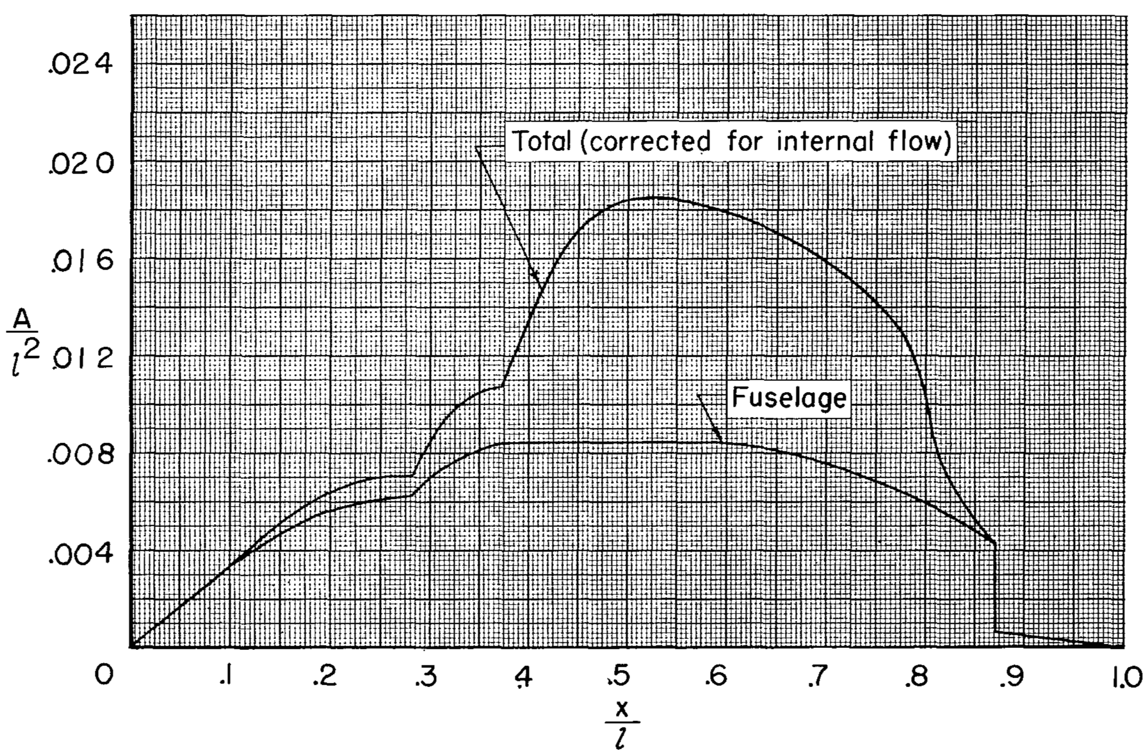
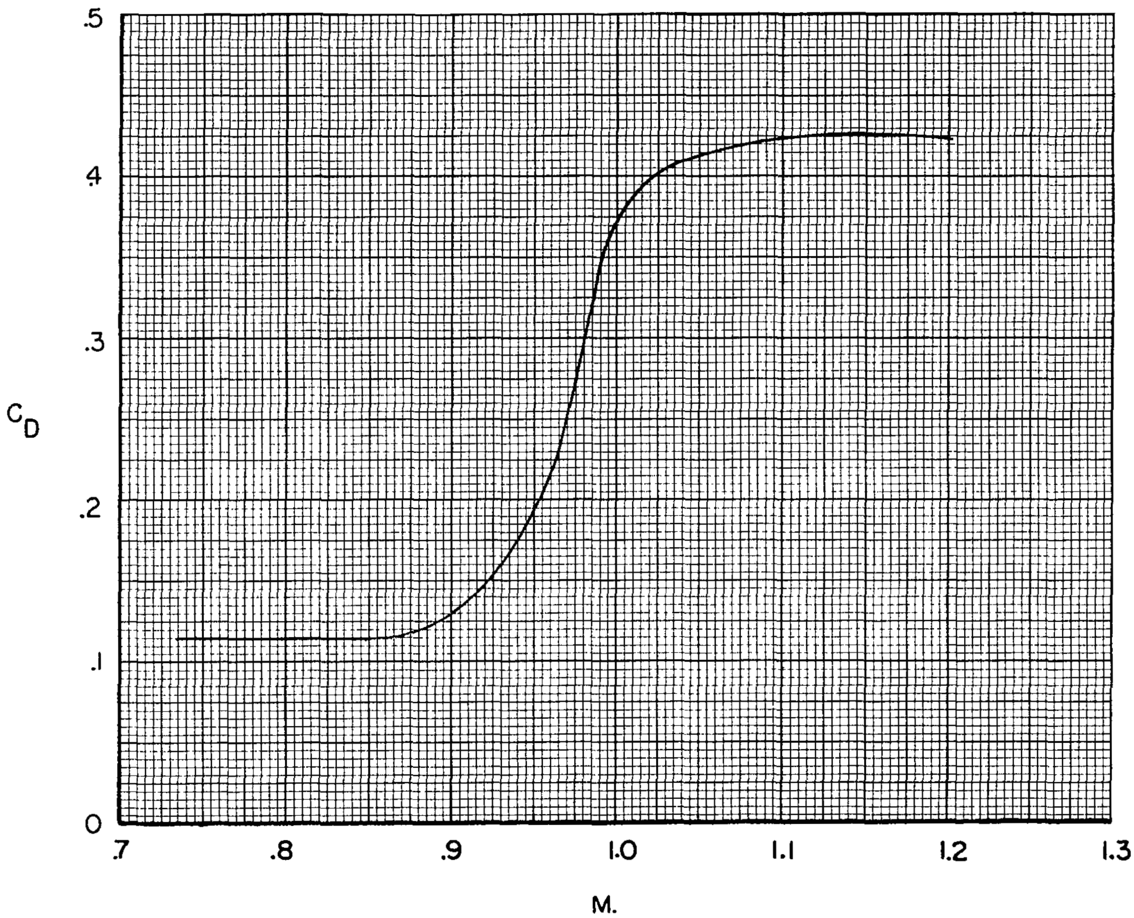


(a) Equivalent body of revolution.



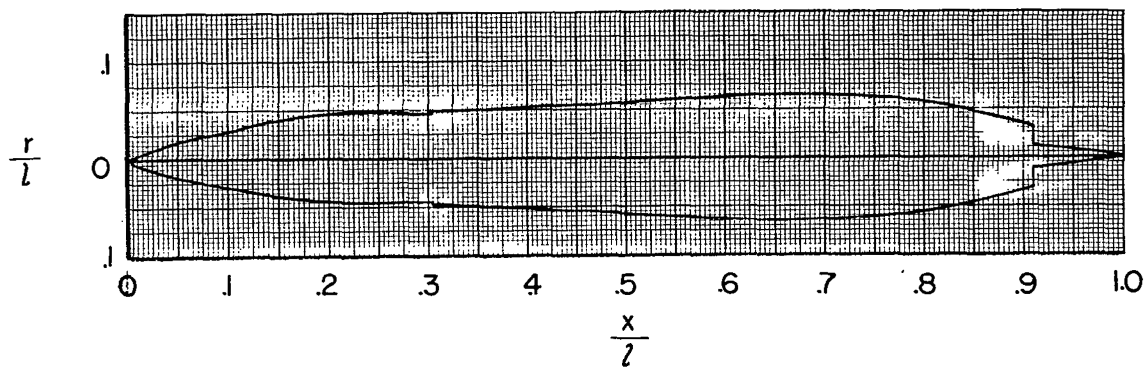
(b) Area distribution.

Figure 6.- Model C.

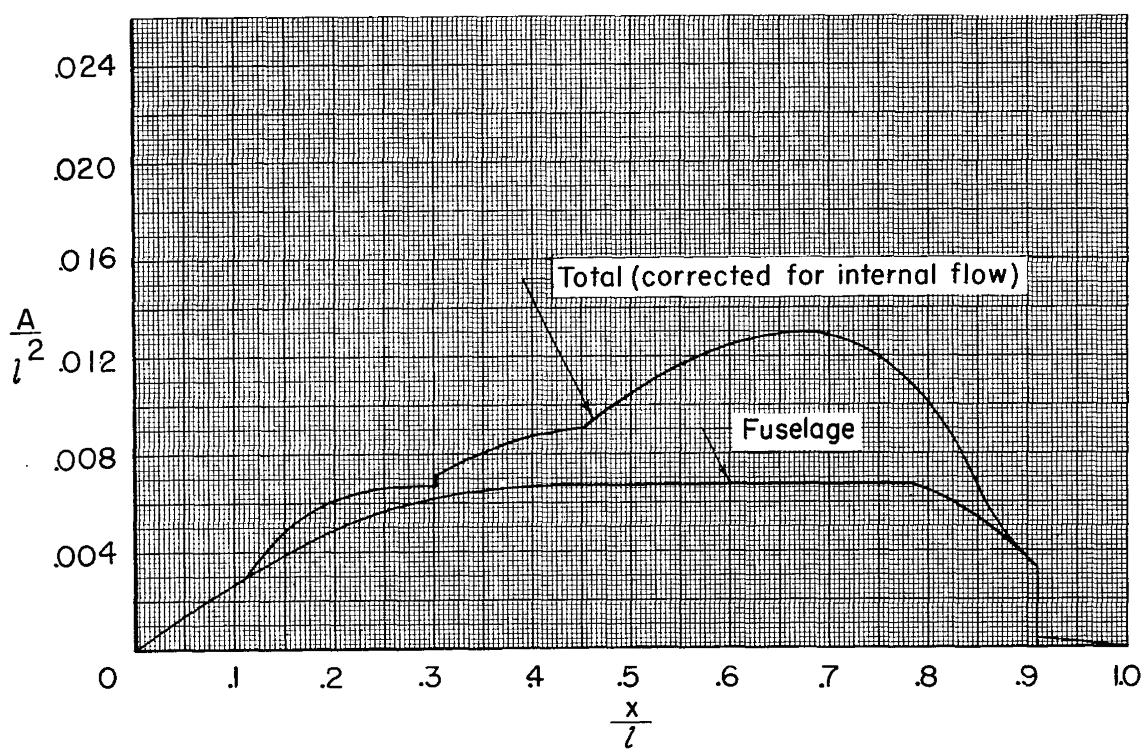


(c) Drag coefficient.

Figure 6.- Concluded.

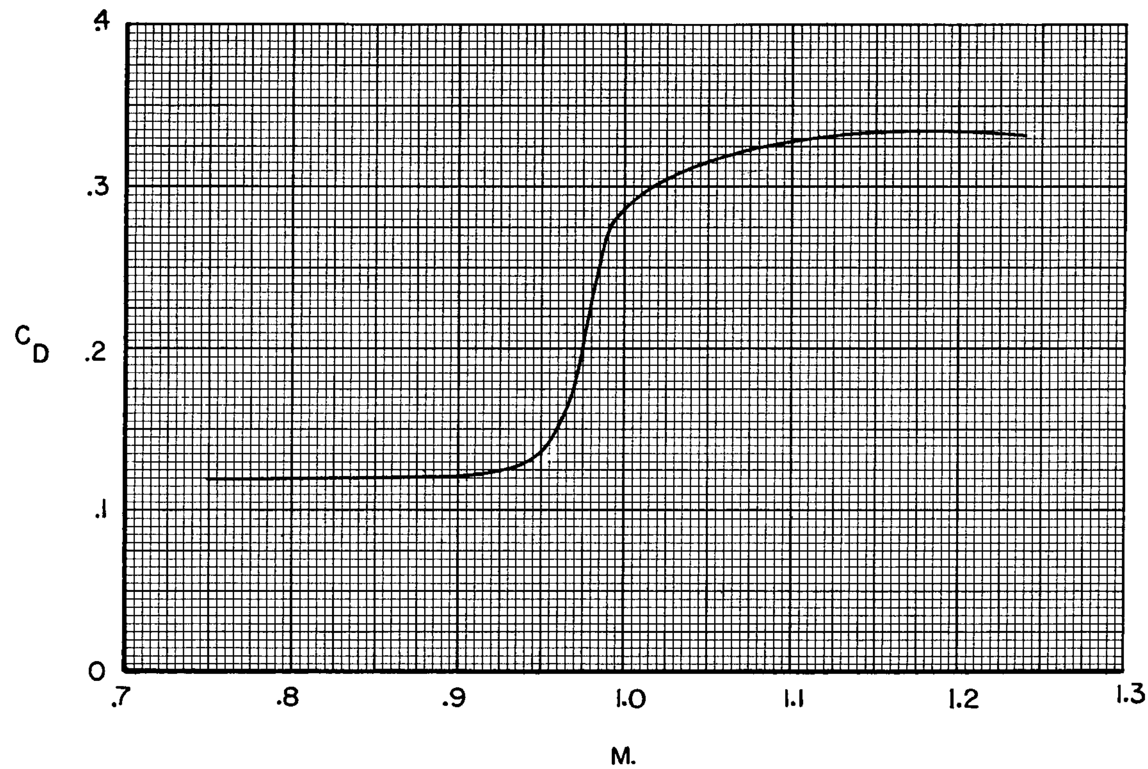


(a) Equivalent body of revolution.



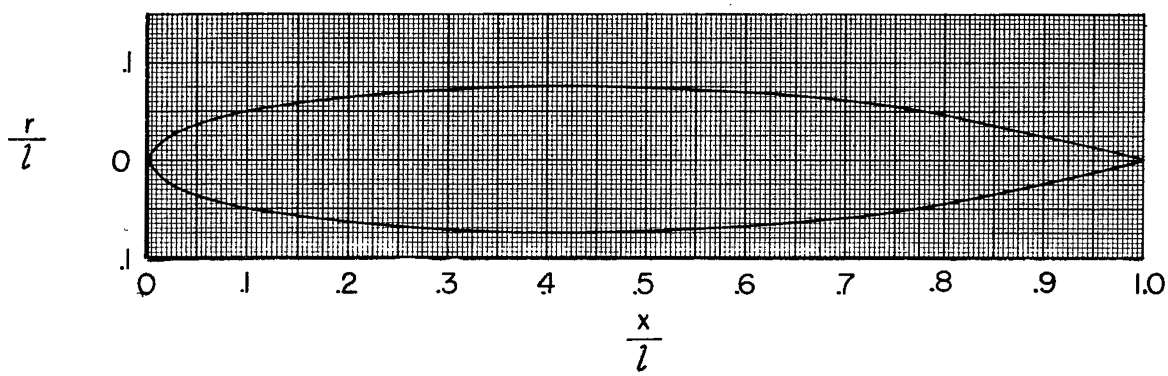
(b) Area distribution.

Figure 7.- Model D.

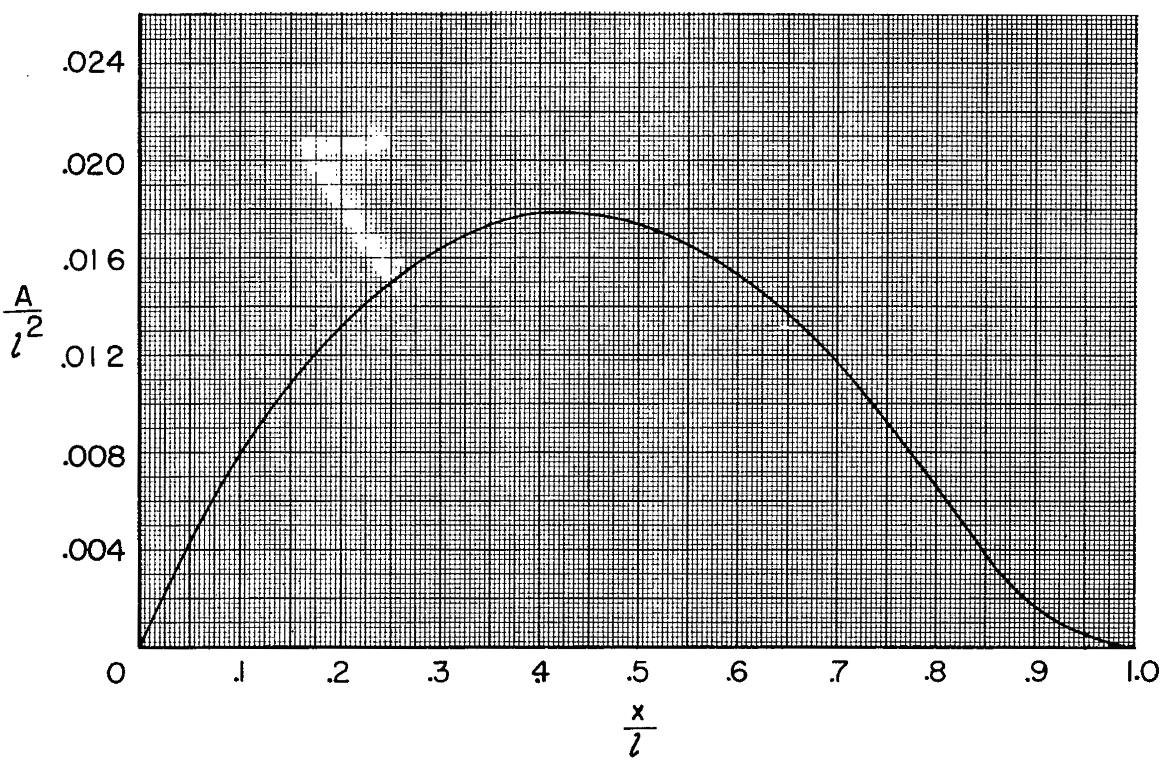


(c) Drag coefficient.

Figure 7.- Concluded.

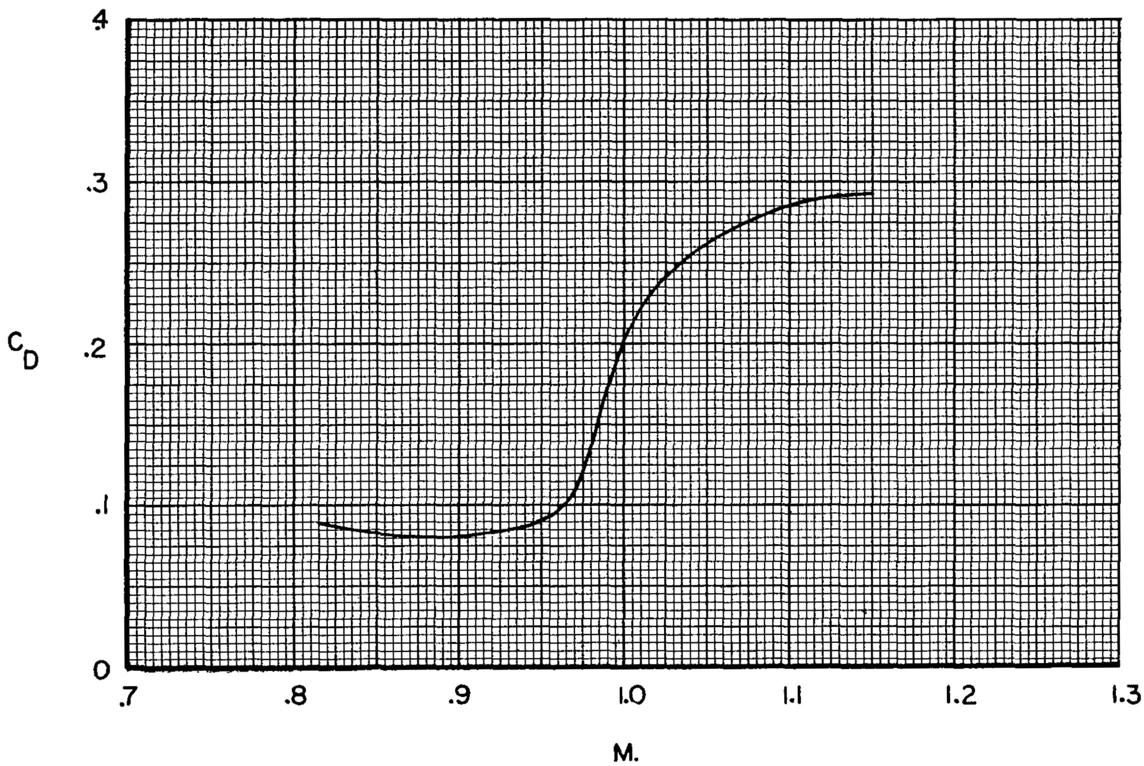


(a) Equivalent body of revolution.



(b) Area distribution.

Figure 8.- Model E.



(c) Drag coefficient.

Figure 8.- Concluded.

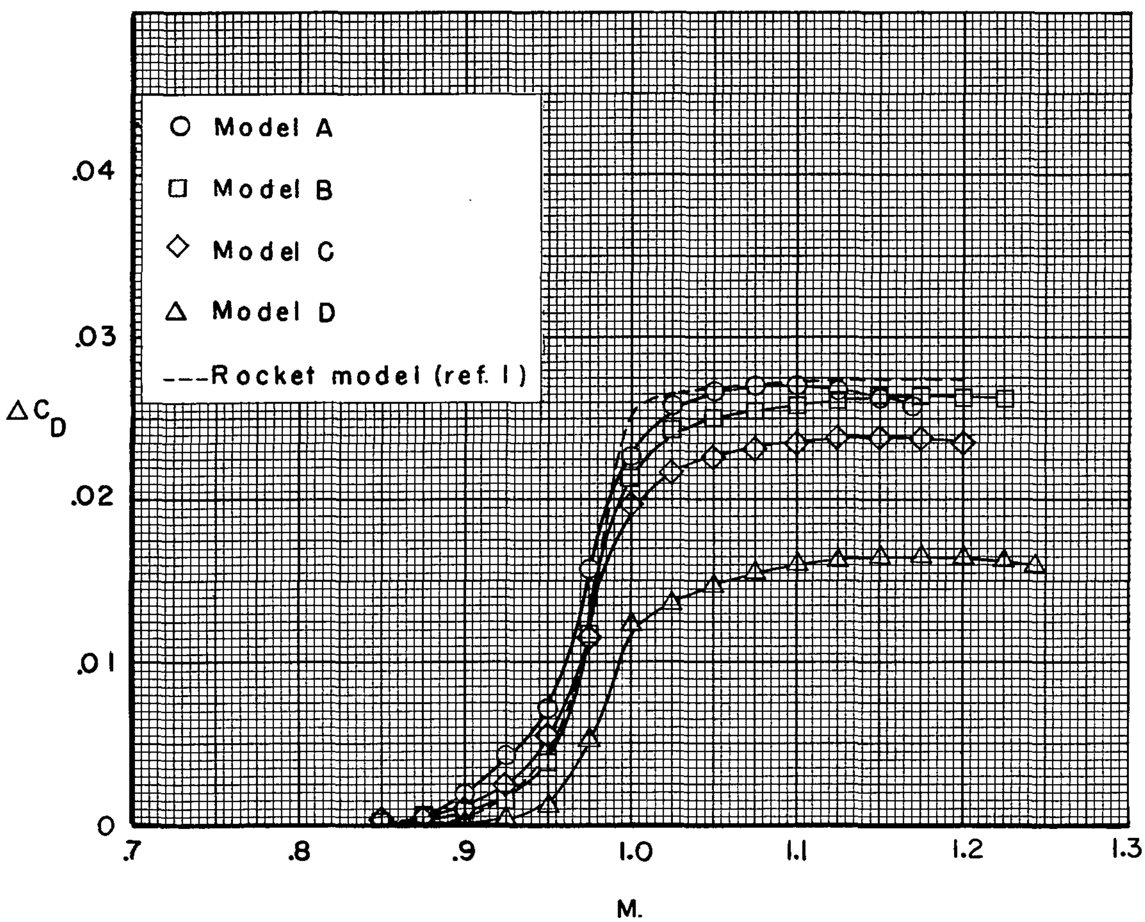


Figure 9.- Drag-rise coefficient (based on wing area).

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